ESTCP
Cost and Performance Report

(MM-0327)

Remote Excavation of Heavily Contaminated UXO Sites

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ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
BT#2	Bomb Target #2
COTR	contracting officer's technical representative
DDESB	Department of Defense Explosives Safety Board
DGM	digital geophysical mapping
EE/CA	Engineering Evaluation/Cost Analysis
ESS	Explosives Safety Submission
ESTCP	Environmental Security Technology Certification Program
E-Stop	emergency stop
FLBGR	Former Lowry Bombing and Gunnery Range
GPS	Global Positioning System
HEI	high explosive incendiary
MEC	munitions and explosives of concern
MSD	Minimum Separation Distance
OB/OD	open burning/open detonation
RF	radio frequency
RPM	revolutions per minute
Shaw	Shaw Environmental Services
SUXOS	senior UXO supervisor
Timberline	Timberline Environmental Services, Inc.
USA	USA Environmental, Inc.
USACE	U.S. Army Corps of Engineers
USAESCH	U.S. Army Engineering Support Center, Huntsville
UXO	unexploded ordnance
UXOSO	UXO safety officer

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- Environmental Security Technology Certification Program (ESTCP). As the lead funding agency, ESTCP provided the means to develop and demonstrate the Range Master technology.

- U.S. Army Engineering Support Center, Huntsville (USAESCH) and Scott Millhouse. USAESCH was also a funding agency, with Scott Millhouse serving as a mentor during the effort. Scott's faithful support was critical in maintaining project momentum and in establishing the Phase I demonstration site.

- Timberline Environmental Services, Inc. (Timberline). Timberline, and most notably Mr. Terry Northcutt, was the heart and soul of this project. Range Master is Terry's idea, from start to finish.

- The U.S. Army Corps of Engineers (USACE), Omaha District. The Omaha District of the Corps provided the Phase II demonstration site and Ordnance and Explosives Safety support. Their ordnance and explosives contractor, Shaw Environmental Services (Shaw), provided critical support in getting the Explosives Safety Submission (ESS) approved and the demonstration work plan reviewed. Shaw also supported the site soil sieve tests, and provided the pre-excavation and post-excavation site surface sweeps, unexploded ordnance (UXO) escort throughout the demonstration, and final assessment of the objects recovered by Range Master. Their digital geophysical mapping (DGM) contractor, Sky Research, Inc., supported the site soil sieve tests and provided pre- and post-excavation DGM data of the demonstration area.

1.0 EXECUTIVE SUMMARY

1.1 BACKGROUND

Many formerly used defense sites, base realignment and closure sites, and active ranges have areas that are heavily contaminated with munitions and explosives of concern (MEC) or unexploded ordnance (UXO), range residue, and contaminated soils. These areas include open burning/open detonation (OB/OD) areas, old or current target impact areas, strafing ranges, 40-mm ranges, and small arms ranges with very high concentrations of surface and subsurface metallic signatures that would reduce the effectiveness of digital geophysical mapping (DGM). Remediation or maintenance of these sites is hazardous, time-consuming, and expensive. Characterizing these sites with DGM techniques can help to confirm the degree of contamination, but these techniques are currently unable to provide sufficient resolution to properly estimate remediation or maintenance efforts.

A robust, remotely operated UXO excavation system such as the Range Master, with replaceable armor, chains, paddles, and screens, would provide a cost-effective tool to:

- Remediate heavily contaminated UXO sites to depths of 12 inches below ground surface (bgs)
- Clear range clutter and UXO for identification and disposal in a single pass
- Remove polluted soils for treatment or to perform deeper remote clearance operations as a design option to hold and carry excavated soils (Note that additional design and modifications are required to hold and carry excavated soils.)
- Prepare and optimize heavily contaminated UXO sites for deeper and more effective DGM characterization and remediation.

An ability to remotely screen and observe excavated objects and suspected UXO items for disposal would improve the efficiency and safety of near-surface (i.e., surface to 12 inches bgs) “mag and dig” or mechanical sifting operations.

The optional integration of survey-level differential Global Positioning System (GPS) and Autopilot control equipment could facilitate effective area clearance to customer specifications.

This project was developed in two phases. Phase I provided the primary technology integration of the base carrier and screening system that is manually operated. Phase II incorporated system armoring and remote control components. This report documents the Phase II costs and performance.

The project organization is as follows: the Environmental Security Technology Certification Program (ESTCP) is the primary sponsor; the U.S. Army Engineering and Support Center, Huntsville (USAESCH) provided initial project seed money and provided contracting officer’s technical representation (COTR); USA Environmental, Inc. (USA) is the prime contractor responsible for project management and UXO support; and Timberline Environmental Services,

Inc. (Timberline) is responsible for system design, fabrication, integration testing, and demonstration operation and maintenance.

The U. S. Army Corps of Engineers (USACE), Omaha District, provided access to the former Lowry Bombing and Gunnery Range (FLBGR), Bomb Target #2 (BT#2), and the ordnance and explosives safety officer. Shaw Environmental Services (Shaw) supported the soil screening tests and provided Ordnance and Explosive escort and any required ordnance disposal. Shaw also performed the initial and final surface sweeps and recorded all excavation results (recovered object identification and estimated weight). Sky Research, Inc., provided the "before" and "after" DGM of the demonstration site.

1.2 OBJECTIVES OF THE PHASE II DEMONSTRATION

The Phase II system demonstration was conducted at the FLBGR, Colorado. The specific site selected for the Phase II demonstration was BT#2. This portion of FLBGR had a high concentration of ordnance, was in the process of being cleared, offered excellent logistics support, and had relatively flat terrain. The objectives for this demonstration were:

- To demonstrate the Range Master's ability to safely and effectively excavate portions of a live ordnance site
- To demonstrate the success of the project in terms of:
  - Faster excavation and screening time
  - Cheaper excavation and screening costs
  - Improved site conditions for follow-on DGM
  - Identifying design areas that would need to be improved in order to robustly survive the rigors of sustained field work.

The specific metrics that were demonstrated are included in Section 3.1.

1.3 REGULATORY DRIVERS

Because the Range Master is designed to be operated in heavily contaminated UXO environments, a technology approval by the Department of Defense Explosives Safety Board (DDESB) was required for the Phase II demonstration and will likely be required for each live MEC project site. This was accomplished through an addendum to the existing site Explosives Safety Submission (ESS).

Site sensitivities to local flora, fauna, habitat, and archeological significance must be considered in advance, as the Range Master is an excavation tool. State and local authorities may also need to be consulted for authorization to excavate.

1.4 DEMONSTRATION RESULTS

Table 1 summarizes the demonstration objectives and results.

Table 1. Range Master Phase II Demonstration Results Summary.

Type of Performance Objective	Primary Performance Criteria	Expected Performance	Actual Performance
Qualitative	1. Safety	Safe remote operation, no equipment damage	Successful. No personnel or equipment damage
	2. Ease of use	Operator acceptance	Better than manual operation. Need better track guidance and scraper experience.
	3. Improved geophysical site conditions	Reduced clutter, improved detection of deeper objects	Unsuccessful. Operator's inexperience in scraper operation resulted in uneven depth of excavation. Many objects below excavation depth.
Quantitative	1. Excavation rate	1 to 2 acres per day	2 days per acre.
	2. Item recovery effectiveness	90%	Unknown, as site has not been fully cleared. 2,133 items were excavated (508 pounds).
	3. Effective depth of excavation	At least 12 inches consistently excavated	Not achieved. Excavations ranged from 18 to 0 inches.
	4. Downtime	<20% downtime	Successful. Excavations ranged from 18 to 0 inches.
	5. Reduced number of DGM anomalies	Before and after dig lists show reduced anomaly density.	Not calculated.
	6. Reduced excavation costs	Per acre costs below costs for manual excavate-and-sift (e.g., $51.5K/acre from pre-Phase I)	Successful. Demonstrated $46.235K/acre, a $4.093K savings over conventional excavate-and-sift at $50.328K/acre.

1.5 STAKEHOLDER/END-USER ISSUES

Assessment of stakeholder and end-user concerns includes the following:

- Unintentional detonation of UXO items exceeding the protection limit of the system armor (e.g., UXO larger than a 105-mm projectile). It is expected that proper planning should limit Range Master application to areas where the expected range of UXO will not exceed the protection limits. The most sensitive components (e.g., hydraulics and power plant) were armored in Phase II and sacrificial components (e.g., paddles and screens) are field replaceable. In the event of catastrophic damage to the armored prime mover from larger UXO detonations, the Range Master would need to be pulled from the range for repair back along the path it has already cleared. A standard tow point is provided. Note: No unintentional detonations were experienced during the six excavation days at FLBGR BT#2.
- Fuel, oil, and hydraulic fluid spills are a concern with operating heavy equipment in hazardous environments. Industry-standard spill containment and recovery equipment were on hand at all times and exercised during this demonstration.

- UXO areas with environmental sensitivities (e.g., flora, fauna, archeological) will limit application.
- Technology acceptance and utilization by UXO remediation contracting organizations, contractors, property stakeholders, and regulators must be considered. Safety and effectiveness will need to be successfully demonstrated before this technology is accepted for commercial application.

Area terrain, vegetation, soil conditions, and weather will limit the application of the Range Master. It is expected that the Range Master will operate in terrain with vertical slopes less than 35%. Vegetation must be cleared for soil access (during the Phase I and II Demonstrations, it was noted that the Range Master can clear nominal site vegetation). Site soils must be free of significant roots (e.g., greater than 4-inch diameter) and noncohesive (e.g., dry loam, sand, or small cobble gravel). Wet and frozen soils will degrade the performance of the Range Master, as shown in the Phase I Demonstration. Sites with loose, dry soils will generate large dust clouds that may require engineering controls or, at a minimum, modified deployment strategies. The site selected for the Phase II demonstration was not designed to validate all of these expected limitations.

2.0 TECHNOLOGY DESCRIPTION

Heavily contaminated MEC and UXO sites are often cleared using standard excavators and power sifting equipment. Using this technique, site soils are excavated, transported to the power screen, sifted, and the soil returned to the site. This conventional method is hazardous (range material is handled multiple times), expensive, and time consuming. Range Master was developed to perform this type of clearance remotely (safely) and effectively by performing the excavation and sifting in a single operation.

2.1 TECHNOLOGY DEVELOPMENT AND APPLICATION

Range Master uses current proven and mature technologies that are in commercial use today. The base carrier (see Figure 1) consists of a modified Caterpillar 633D Scraper that is manually operated. The modifications for Phase I included (1) the removal of the scraper's clamshell and its control components, (2) the design, fabrication, and installation of a backing plate to lift site soils to the integrated power screening system, and (3) the purchase, design, and installation of the screening system. The screening system is tilted and provides hydraulic screen shaking. Objects that are too large to pass through the screen network (primary and secondary screens) fall into a wire mesh hopper at the back of the Range Master. The operator controls the hydraulic dumping of the screened hopper contents for examination by UXO personnel. Designed specifically to handle UXO up to 105-mm projectiles, the Range Master is physically capable of handling much larger ordnance (e.g., 500-lb bombs) up to the limits of the lifting paddles. Sifted soil drops through the screen unit back onto the site directly under the Range Master. When the screened item hopper is full, the operator hydraulically dumps its contents directly below the Range Master for inspection. OB/OD areas, old or current target impact areas, strafing ranges, 40-mm ranges, and small arms ranges with very high concentrations of surface and subsurface metallic signatures that would reduce the effectiveness of DGM are all areas where Range Master could be applied.

Figure 1. Range Master Base Carrier.

Sacrificial components, such as paddles, chains, and screens, are low-cost items. Spares of these items are maintained on site to minimize downtime. In most cases, replacement of these items can be completed in less than 2 hours.

The Phase II Range Master was developed in two stages. Stage 1 was funded by USAESCH and prepared the base carrier for the integration of the screening unit. Stage 2, funded by ESTCP, included the screening system purchase, modification, installation, control, system integration testing, and the Phase I manual demonstration (see reference 1, Phase I Final Report). The Phase I demonstration success resulted in Phase II, where the system armoring and remote control were added and the Phase II demonstration was performed (see reference 2, Phase II Demonstration Plan, and reference 3, Phase II Final Report).

The Phase II Range Master hydraulics, engine, and cab were armored with armor plates and glass over all vital components. The armor plate was mounted outside the existing shielding. An industry standard remote operating system was integrated in Phase II. Armored cameras provided all views (front, back, sides, and screening areas) to the system operator and UXO technician. Selectable sifting screens, down to 3/4 inch, can be remotely emptied during operation for a more thorough identification or disposal of discovered UXO. Screened soil is immediately returned to the site.

2.2 PROCESS DESCRIPTION

The Range Master integrates a commercial construction excavator with an industry-standard powered soil screening system. Typically these functions are performed serially. Site soils are excavated and hauled to the screening system. Soils are then fed and processed through the screen. Sifted soils are typically returned to the site, while screened items are inspected for potential MEC and disposal.

This serial approach to sifting site soils for potential MEC is time-intensive and costly. The development of the Range Master integrates the excavation and screening unit to optimize operations that require soil sifting. The intended use of the Range Master is to provide a tool that is capable of excavating heavily contaminated UXO sites. Excavation includes all site debris larger than the selected screen mesh.

2.2.1 Phase I Development

During Stage 1, the base carrier was modified for the integrated screening unit. Under Stage 2, the screening unit was purchased, modified to fit in the Range Master, and installed. The hydraulic controls were modified to power the screens and to open and close the hopper. Stage 2 ended with the Phase I demonstration (Figure 2).

Figure 2. Range Master at Phase I Demonstration (Manual Operation).

2.2.2 Phase II Armoring

During Phase II, the Range Master armoring was designed and installed. The armoring was designed to protect critical system components (e.g., engine, fuel and hydraulic tanks) from an unintentional detonation from UXO, up to a 105-mm projectile. The cab was armored to protect an operator from an unintentional detonation from UXO, up to a 75-mm projectile. The armor requirement to protect an operator from the overpressure of larger UXO was too heavy and too expensive for the limited scenarios where the system would be manually operated (e.g., sites where UXO is not expected to exceed 75 mm or to retrieve the Range Master off a range over the path it has already excavated, should the remote control fail). Protection from direct blast was accomplished by adding 0.75-inch A527 steel plates. Areas exposed to indirect blast were covered with 0.5-inch A527 steel. The cab windows were replaced with 2.69-inch safety glass. The cab was armored the same as devegetation equipment that is used to clear vegetation on UXO sites.

2.2.3 Phase II Hopper Upgrade

The Phase I screened hopper design was modified so it did not contact and drag on the ground when fully open. Figure 3 shows the original hopper design and the Phase II design. The upgraded hopper design increased the hopper capacity from 3.34 cubic yards to 3.44 cubic yards.

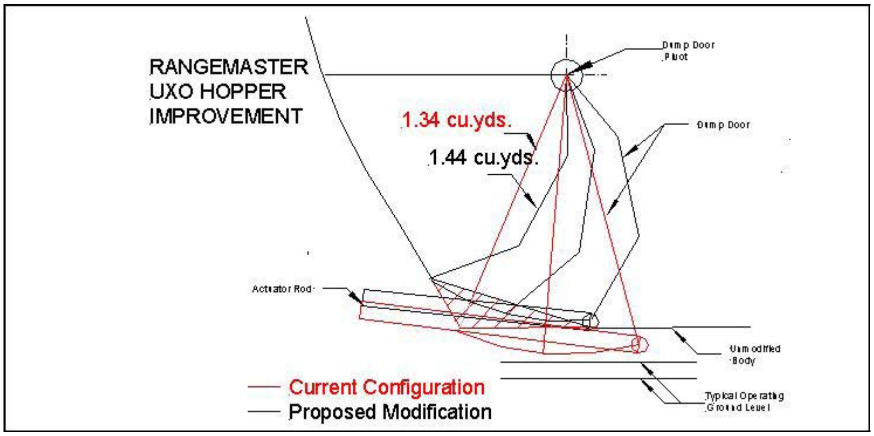

Figure 3. Phase I and Phase II Hopper Design.

2.2.4 Phase II Video and Remote Control

The Phase II remote control system was designed and implemented. This design provides video and control over two radio frequency (RF) links to the remote control platform (a customized recreational vehicle trailer). The video link is provided by a commercial-off-the-shelf RF link operating in the 2.3- to 2.55-MHz range. The effective power of each video transmitter is approximately 4 watts. Six cameras were mounted on the Range Master. Camera 1, wide angle forward looking, provides the primary navigation view. Camera 2 is a pan, zoom, tilt camera mounted high on the front to provide a 360° view. Camera 3 monitors the cutting blade. Camera 4 provides a view of the power screen and allows real-time monitoring of recovered objects if the dust is not too great. Camera 5 is the rear view camera for backing up and monitoring excavation results. Camera 6 is mounted inside the cab and provides a view of the instrument cluster (e.g., engine revolutions per minute [RPM], temperature, hydraulic pressure) to the remote operator. The operator can switch any of the cameras to any of the monitors.

The remote control platform hosts a safety key lock as the master on/off switch. This key is taken by the UXO safety officer (UXOSO) whenever the Range Master needs to be serviced, preventing any possibility of unintentional remote operation. The telemetry provides control of all Range Master functions, including engine on/off, throttle, steering, breaking, blade control, shaker on/off, and hopper open/close. A flashing beacon on top of the Range Master indicates that the vehicle is under remote operation. A mechanical telltale provides visual confirmation that the hopper is closed. As a safety feature, the telemetry system shuts down if the telemetry radio link is broken. This precludes a runaway Range Master. Additionally, three mechanical emergency stop (E-Stop) switches mounted on Range Master can be manually activated, as well as an E-Stop switch on the remote operator’s console. These switches turn off the engine and interrupt power to the remote control.

The remote control telemetry link is a commercial-off-the-shelf Ethernet radio operating in the 902- to 928-MHz range, with output power typically less than 1 watt. The remote control platform is designed in the rear portion of a mobile home and is powered by an auxiliary 5.5-kilowatt generator.

Mobilization costs are a significant consideration. The Phase II Range Master requires a 9-axle trailer to handle the weight of the armored system versus the 7-axle trailer used for the Phase I system. The short-haul mobilization costs for just the Phase II Range Master are estimated at $18.00 per mile. For long hauls, a combination of rail and trailer mobilization might prove to be more cost effective but must provide adequate loading and unloading facilities that are not normally available.

Figures 4, 5, 6, and 7 show the Range Master Mobilization, the Phase II Range Master, the remote control platform ready for the Phase II demonstration, and a view of the operator controls and video monitors.

2.2.5 Theory of Operation

Once a site is identified and the expected range of UXO is anticipated to be equal to or less than a 105-mm projectile, and the site environmental sensitivities and conditions are not severe, the Range Master could be considered as a tool to help remediate the site.

In theory, the Range Master excavates a 12-ft-wide swath. The depth of excavation (typically 12 inches below ground) is controlled by two hydraulic rams that lower or lift the scraper blade. Site terrain also affects the depth of excavation. A set of chain-driven paddles lift soil from the blade up the backing plate to the integrated power screening unit. Excavated soils and debris fall onto the tilted screening unit. The two-stage screen mesh (i.e., coarse and fine) are selected to best meet project object recovery requirements. The screen system is hydraulically shaken to facilitate sifting soils from debris. Sifted soil and debris smaller than the fine screen mesh fall directly back onto the site. Objects larger than the fine screen mesh work their way down the screen surfaces and fall into a wire mesh hopper. At the end of an excavation line, or set of lines, the operator positions the Range Master at an identified dump location and opens the hopper to dump its contents directly under the Range Master. This operation can be performed with the Range Master stationary or while it is moving if it is necessary to spread the dump over a larger area.

The Range Master’s preferred direction of travel is downhill to maximize forward momentum. It was expected that parallel lines of excavation would work best. However, the Range Master tends to tilt when it straddles excavated and unexcavated portions of the site. The Phase I and Phase II Demonstrations used parallel sets of excavation lines separated by a small distance. Subsequent passes were used to excavate the “Mohawk” portions left between passes.

Qualified UXO technicians examine the dump piles to identify potential MEC. Identified UXO can be blown in place or, if it is considered acceptable to move, excavated UXO can be moved to a consolidated location for disposal. At regular intervals, the UXO Technicians also inspect the Range Master for any objects that may have become lodged. If an MEC item becomes lodged (e.g., in the screens) and cannot be moved, it would be blown in place and any damage to Range Master repaired.

This process is continued until the entire site has been successfully excavated to the desired depth.

Figure 4. Range Master Transported on Nine-Axle Trailer.

Figure 5. Range Master at Phase II Demonstration (Armored and Remote Controlled).

Figure 6. Phase II Remote Control Platform and Tow/Support Vehicle.

Figure 7. Remote Control Platform Video Monitors and Control Station.

2.3 PREVIOUS TESTING OF THE TECHNOLOGY

2.3.1 Preproposal Testing

The original, preproposal Range Master tests were conducted to ensure that the prime carrier had the ability to go intrusive at a range of depths and in different soil types. The soil types tested combined sand and loam, and at times contained up to 20% moisture but, for the most part, were optimally dry. While going down an approximate 20% slope, the prime carrier demonstrated the ability to go intrusive to a depth of about 30 inches. While climbing up the same slope, the prime carrier was able to go intrusive to a depth of 18 to 20 inches. Traction effort while climbing hills causes a decrease in the depth of intrusion. Average depth of excavation in the sand and loam soil was 18 inches. Production rate of the prime carrier has been measured at approximately 900 tons per hour. This is done in order to accurately measure and gauge the prime carrier's ability along with the screening unit, which was later integrated into the machine.

The screening unit was tested independently at the same time. The screening unit used a PowerScreen, which is manufactured in Ireland specifically for screening this type of material.

The throughput capability of this particular screen is approximately 800 tons per hour. This puts the production rate about 100 tons less than that of the prime carrier, but by slowing the rate of the prime carrier, we should be able to match the excavation and screening production rates. Throughput is determined or adjusted depending on soil types, moisture content, rock, and other materials that transit through the double screen. Initially, we began screening for 37-mm projectiles, which was the target ordnance item of concern. The first test conducted used a 2-inch primary screen mesh and a 0.5-inch secondary screen mesh. In the preproposal test area, the soil was contaminated with machine gun links and other small items. It was determined that the 0.5-inch secondary screen mesh was too small and was being blinded. Blinding of the screen occurs when the items block the screen and do not let the soil pass through. The soil then just sloughs off the top of the screen. A change was made to a 1-inch secondary screen mesh. This allowed the capture of the 37-mm items and let the machine gun links and smaller material pass through the screen and be redeposited on the screened soil. Increasing the secondary screen mesh also helped to match the production rates of the screen to the prime carrier. Once these two mechanical subsystems had been tested and proven, the integration of the components began.

2.3.2 Phase I Integration Testing

The inner workings of the can on the carrier were removed, and a backing plate was installed. Testing has been done at Timberline's facility to ensure the movement of the elevator paddles can be achieved in any position with the stationary backing plate in place. Full range of motion has been achieved. The next test conducted was to ensure that all materials go through the screening process. Custom-made components had to be fabricated outside the Timberline facility. Timberline cannot roll and shape 1-inch steel plate. Once the custom-made components were installed, tests were performed to ensure complete movement of the elevator paddles. The rear ejector circuit has been tested and is proving to be more than adequate to dump the screened items retained in the hopper (basket unit) after going through the screens. Screened items are

retained in the hopper so that they do not re-enter the soil. A proprietary valve was installed to ensure adequate flow and pressure to the screen system.

2.3.3 Phase I Demonstration

The Phase I system demonstration was conducted at the former Fort Ord, Monterey, California, Range 18. This site was selected for the following reasons:

- Proximity to Timberline's facilities to minimize mobilization costs
- Known site history, including potential UXO and cleanup efforts
- Known terrain and soil conditions acceptable for the Phase I Demonstration
- Facility interest in potential Range Master use
- Because Range 18 has been used as a small arms range during the entire history of this range.

This was a controlled test site that was constructed with known seed targets (e.g., pipe sections to simulate 40-mm grenades, 60-mm and 81-mm mortars, and 105-mm projectiles) and machine shop clutter objects, with more realistic terrain and vegetation conditions. USA mobilized the senior UXO supervisor (SUXOS), UXOSO, principal investigator, and all DGM equipment on February 16, 2004. Timberline mobilized the system operator, maintenance mechanic, the project manager, and the range master itself, on February 17, 2004. The Phase I Range Master required a 7-axle trailer for mobilization from Timberline's assembly facility in Cold Springs, California, to the Former Fort Ord in Monterey, California.

Two 100- x 100-ft grids were selected on Range 18. Parsons provided existing background EM61 data for the range and for these two grids. USA performed a 100% background check using handheld Schonstedt magnetic gradiometers. Both sites were completely clear and no surface or subsurface ferrous metals were detected.

Grid 1 was seeded with 50 each 60-mm mortar simulants, 60 each 81-mm mortar simulants, and 196 pieces of metal clutter buried flush with the surface (0 inches) and at 3, 6, and 12 inches below ground.

Grid 2 was seeded with 110 each 40-mm grenade simulants and 196 pieces of metal clutter buried flush (0 inches) and at 3, 6, and 12 inches below ground. In general, seed items along the south edge are flush with the surface and are buried deeper as each line moves north.

The Phase I demonstration resulted in a recommendation to transition into Phase II.

2.3.4 Phase II Integration Testing

The Phase II Range Master went through integration testing at a quarry in Livermore, California, on October 13 and 14, 2005. Range Master was remotely operated up to a range of 1.4 miles. When the telemetry link was lost, the system shut down as designed. Raising the antennas at the remote control platform would increase the operating range.

All E-Stops were exercised successfully. These include the rear and both side E-Stop buttons mounted to Range Master's exterior, the key “off” master switch in the cab, the circuit breakers providing power, the remote control console E-Stop button, and two software E-Stops.

Two 13-ft-wide by 800-ft-long test runs were established and seeded with twenty 40-mm and 81-mm simulants. Two simulants were placed on the surface; the rest were buried 8 inches deep. Three passes were made over the test lane, each averaging 7.75 minutes. The hopper was dumped approximately every 125 ft. Nineteen simulants were recovered. Three of the recovered simulants were crushed due to the hard, rocky nature of the quarry.

All video cameras were adjusted to provide optimum feedback. The split screen monitors all worked well. The air nozzles mounted to each camera kept the lenses clean even under very dusty conditions.

The remote control platform design was well accepted by all designers and by the operator. Telemetry functions all worked. The steering control was adjusted to reduce sensitivity and improve performance.

The cab’s air conditioning needs to be working to keep electronics cool. Otherwise, the system shuts down, as experienced during the Phase II integration testing. Overall, the Phase II Integration testing was successful.

2.4 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The Range Master technology was developed for the purpose of greatly reducing the human element involved with the cleanup of heavily contaminated UXO sites. The technology is sound and does work; however, the Phase II Demonstration identified the need for an experienced excavator as the remote system operator. Specific advantages of the Range Master include:

- Remote (safe) excavation and sifting with an integrated system
- Improved excavation rates and cost over conventional excavate-and-sift operations.

Technology limitations include:

- Mobilization and demobilization costs are high.
- Soil type and moisture content must be screenable (same as conventional excavate and sift).
- Vegetation must be removed (same as conventional excavate and sift).
- Terrain must be accessible to Range Master in terms of slope and maneuvering room.

3.0 DEMONSTRATION DESIGN

The Phase II Range Master Demonstration was performed from June 18 through 29, 2006, at BT#2 at the FLBGR, Colorado.

3.1 PERFORMANCE OBJECTIVES

The objectives of the Phase II Range Master Demonstration were to:

- Demonstrate remote/safe excavation of an actual heavily contaminated UXO site
- Excavate and successfully screen from the site objects (UXO) of the size and depth advertised (e.g., 20-mm projectiles and larger in the first 12 inches)
- Improve site geophysical conditions
- Track costs to better establish production rates and costs.

The specific metrics to be demonstrated, the expected performance criteria, and the actual performance demonstrated are included in Table 2. The downtime was calculated. Acceptable system reliability during the Phase II demonstration (e.g., less than 20% downtime expected) was demonstrated, including the replacement of the screen shaker coupler, all inspections, and final wash down.

Table 2. Phase II Range Master Demonstration Results.

Type of Performance Objective	Primary Performance Criteria	Expected Performance	Actual Performance
Qualitative	1. Safety	Safe remote operation, no equipment damage	Successful. No personnel or equipment damage
	2. Ease of use	Operator acceptance	Better than manual operation. Need better track guidance and scraper experience.
	3. Improved geophysical site conditions	Reduced clutter, improved detection of deeper objects	Unsuccessful. Operator's inexperience in scraper operation resulted in uneven depth of excavation.
Quantitative	1. Excavation rate	1 to 2 acres per day	2 days per acre
	2. Item recovery effectiveness	90%	Unknown, as site has not been fully cleared. 2,133 items were excavated (508 pounds)
	3. Effective depth of excavation	At least 12 inches were consistently excavated.	Not achieved. Excavations ranged from 18 to 0 inches.
	4. Downtime	<20% Downtime	Successful. Excavations ranged from 18 to 0 inches.
	5. Reduced number of DGM anomalies	Before and after dig lists show reduced anomaly density.	Not calculated
	6. Reduced excavation costs	Per acre costs below costs for manual excavate-and-sift (e.g., \$51.5K/acre from pre-Phase I)	Successful. Demonstrated \$46.235K/acre, a \$4.093K savings over conventional excavate-and-sift at \$50.328K/acre.

Ease of use was assessed and documented during post-excavation interviews with the Phase II Range Master operator and UXO technicians. This includes ease of excavation, soil screening, hopper dumping, and screened item inventorying by UXO personnel. The operator reported that the Range Master was easy to use remotely. He expressed difficulty in seeing excavation boundary markers and maintaining straight line excavations when dust conditions became extreme. All controls (e.g., screen shaker and hopper dump) were accessible and easy to operate. The Range Master base carrier drove and handled normally. The screened item recovery by UXO personnel was satisfactory but was complicated by excess soil in the hopper.

Improvement to DGM site conditions did not result in significantly reduced background and clutter anomalies (e.g., the ability to reduce the effects of near-surface clutter and to enhance the ability to detect deeper objects). A comparison of the pre-excavation EM61 surveys and the post-Range Master excavation EM61 surveys documents that there was little improvement for each grid. This was due to a combination of the operator's inexperience in scraper operation, resulting in uneven excavation depth, and the high density of metal below the excavation depth.

3.2 SELECTION OF TEST SITE

The Phase II system technology demonstration was performed at the FLBGR in Colorado. During the site visit to FLBGR, BT#2 was selected as the most appropriate site for the Phase II demonstration. The reasons for selecting this site included the following.

- This site is actively being cleared and may benefit from this technology demonstration.
- The terrain and vegetation were suitable.
- The site is close to major access roads for optimum logistics.
- There are sufficient cleared areas outside the Minimum Separation Distance (MSD) to:
  - Stage the remote control platform
  - Set up and practice.
- There are ample areas that require remediation.

A set of five adjacent 50-m x 50-m grids, forming a north/south area 50 m (164 ft) wide x 250 m (820 ft) long just east and north of the old target center, were identified for the actual demonstration/remote excavation.

3.3 TEST SITE/FACILITY HISTORY/CHARACTERISTICS

According to the Archives Search Report, a cube-shaped concrete block located in the center of Sector 7 was used as a bombing target during World War II. This area was subsequently designated as Bombing Target #2. This area is currently used for cattle grazing. It is anticipated that the State Land Board property (e.g., BT#2) will convert from cattle grazing to residential use in the future.

The most probable MEC items to be recovered during this demonstration in BT #2 are the 20-mm high explosive incendiary (HEI) projectile, MK23 practice bomb, and MK15 practice bomb. This assumption is in keeping with the site's ESS Addendum 1 and is based on the information

obtained during the Engineering Evaluation/Cost Analysis (EE/CA) dated January 1998. There was a concern that incendiary MEC/UXO items were present at BT#2. Therefore, a water truck was made available to minimize the risk of fire to the site.

There are no known soils or geologic conditions at BT#2 that would preclude a successful test/demonstration of the Range Master. A soil sieve test was performed by Sky Research prior to mobilization to document the suitability of sifting site soil, as a function of soil moisture.

3.4 PHYSICAL SETUP AND OPERATION

3.4.1 Soil Sieve Tests

A soil sieve test was performed to document that the site soils were suitable for screening by Range Master prior to mobilizing the system to FLBGR. A total of ten 5-gallon buckets of soil were collected from the first 12 inches at BT#2 and provided to Advanced Terra Testing, Inc. The soils were air dried to a baseline moisture content of 4.7% from their native moisture content of 9.3%. The soil was dry, dusty, and friable. Two screen combinations were tested. One was a 2-inch primary screen with a 1-inch secondary screen. The other was a 2-inch primary screen with a 0.75-inch secondary screen. Both were combinations used by Range Master. Test results for both screen combinations indicated that the site soils were able to be screened up to a moisture content of 18% to 20%. At these moisture contents, the soil lost its dry characteristics and began to clump and retain soil on the screens.

3.4.2 Pre-Demonstration DGM

Following the initial surface sweep of the five consecutive 50- x 50-m demonstration grids by Shaw, Sky Research performed the pre-excavation DGM of the selected grids. USA processed and analyzed all of the time gates from the EM61-MK2 array deployed by Sky, Inc. The DGM data from time gate 3 showed the best overall response and documented that the grids were heavily contaminated with subsurface metal, typical of areas adjacent to a bombing target. This data was acquired with an array of EM61-MK2 all-metals detectors. The background DGM data documented that the selected demonstration area is a high-density target site with no utilities or geological features to hinder the demonstration.

3.4.3 Range Master Setup

The possibility of 20-mm projectiles required a 0.75-inch secondary screen mesh to capture objects with this diameter and larger. Since no 0.75-inch screens were specifically designed for Range Master, a set of commercial off-the-shelf 0.75-inch screens was purchased and bolted over the 1-inch secondary screens. A hydraulic pump was pulled and rebuilt to proper specifications and reinstalled, the video cameras and antennas were installed, and the cab air conditioning was repaired. There were no special site preparations other than marking the individual grids.

3.5 ANALYTICAL PROCEDURES

No special analytical procedures were used to establish the demonstration site.

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4.0 PERFORMANCE ASSESSMENT

4.1 PERFORMANCE DATA

The primary performance source data is contained in the Range Master Phase II Final Report. These include (1) system safety assessment, (2) the Phase II excavation time log, (3) the itemized object recovery report, (4) post-excavation DGM conditions, (5) ease of use, and (6) downtime.

4.2 PERFORMANCE CRITERIA

USA's UXOSO provided the system safety assessment. The Range Master excavation rates were determined from the excavation time log. The object recovery rate was established from the itemized recovery report from Shaw. Geophysical site conditions after the demonstration were determined from the post-excavation DGM of the grids excavated. Ease of use was provided by the system operator, and downtime was derived from the excavation time log.

4.3 DATA ASSESSMENT

4.3.1 System Safety Assessment

The safety assessment for the Phase II Range Master was good. USA's UXOSO observed all aspects of this demonstration, from setup to cleanup. Personnel working in close proximity to the Range Master were required to wear hard hats. Throughout the demonstration, there were no personnel injuries. The remote Range Master operation was considered safe. There was no design-inherent damage to the Range Master and no damage caused by MEC.

4.3.2 Excavation Rates

Table 3 summarizes the average Phase II remote excavation rates. This data can be used to establish an ideal excavation rate (time per run times the number of runs). Practically, the excavations took longer, taking into account routine maintenance and MEC inspections. The actual excavation rate is derived from the entire demonstration. Table 4 summarizes the ideal, practical, and actual excavation rates.

Table 3. Average Excavation Rates per 50-m Grid.

Average 50-m excavation run	0:07	minutes
Average runs/50-m grid (0.62 acres)	20	runs
Average 200-m reprocess	0:08	minutes
Average 200-m leveling run	0:03	minutes
Average re-reprocess run	0:02	minutes

Table 4. Range Master Phase II Production Rates.

Excavation Rate/50-m Grid				
Ideal	2:31	hours: minutes	4.1	hours/acre
Practical	6:49	hours: minutes	11.0	hours/acre
Actual	1.5	days	2.4	days/acre
Conventional excavate and sift			40	hours/acre

4.3.3 Item Recovery

Following the excavation, Shaw inspected the dump areas and the final dump pile. They also performed a second surface clearance to recover items newly exposed by Range Master and to prepare the site for post-excavation DGM by Sky. Table 5 summarizes the items excavated by Range Master and recovered by Shaw (see Figure 8).

Table 5. Items Excavated by Range Master from BT#2.

Item Excavated	From Dump Piles		From Grids	
Mk 23 bomb	35	each	15	each
Booster cup	3	each		
Booster (M152 fuze)	2	each		
HE bomb frag	1	each		
HE brag	3	each		
OE scrap	2,059	each		
2.25-inch rocket	1	each		
Small arms	11	each		
Non Ordnance & Explosive (OE) scrap	3	each		
Subtotals	2,118	each	15	each
Estimated weight of items excavated	443	lb	65	lb

Figure 8. Photographs of Items Excavated by Range Master from FLBGR BT#2.

4.3.4 Improved Geophysical Site Conditions

Following the second surface clearance, Sky performed the post-excavation DGM of the four grids excavated by Range Master. USA analyzed the data from all four EM61-MK2 time gates. Of all of the time gates, time gate 3 showed the best before-and-after response. All of the post-excavation DGM time gates are more active than the pre-excavation DGM for the following reasons:

1. The soil was loosened by Range Master so the towed array sensor support sank in, moving the sensors closer to the ground.
2. Range Master moved objects and brought them closer to the surface but failed to capture and remove them.

The site is close to target center and is truly cluttered with metal at a full range of depths with much, if not most, below 12 inches. Range Master was successful in removing much of the near-surface metal but failed to get it all within its operational design (the first 12 inches). From the post-excavation DGM data, it is clear that a significant amount of the subsurface metal remains below the Range Master's excavation depth (typically 12 inches). In hindsight, this is to be expected for a bombing target.

No target analysis was performed on the DGM data. However, a comparison of the pre-excavation DGM maps with the post-excavation DGM maps (before and after) demonstrates that there was little to no significant improvement in site geophysical conditions. For the first live site demonstration of the Range Master, USA is pleased with these results.

4.3.5 Ease of Use

The Phase II Range Master (armored and remote controlled) proved easier to use than manual operation. This is attributed to the video provided, which afforded the operator an all-around view. The display of the instrument cluster and the audio from the Range Master cab proved to be invaluable in monitoring and operating the system.

The single remote control key in the control platform provided the necessary safety assurance during all required maintenance and inspections (this key was given to the UXOSO to prevent any accidental remote operation). Although used only during setup, the E-Stop switches provided an extra level of safety. The flashing strobe on top of the Range Master provided a clear indication that the system was in remote operation.

The dust created during excavation occasionally limited visibility. This most affected the visibility of the start and end marks (orange marking paint) for the excavation area. A GPS with the site boundary and planned tracks would help greatly. Limited visibility also obscured the screening area, making it difficult at times to judge the soil processing rate.

4.3.6 Downtime

Downtime was calculated from the time the Range Master was on site through the Phase II demonstration. The Range Master was available for operations a total of 9 days 24 hours/days, or 216 hours. The Range Master does require regular maintenance. Table 6 summarizes the maintenance performed during this demonstration. The first 2 days on site were spent preparing the system for demonstration. Regular MEC inspections, system restarts, and cleaning camera lenses were routine. Removing the 0.75-inch screen over the 1.0-inch secondary screen required extra maintenance time, as did the repair of the screen shaker coupler. It proved advantageous that the demonstration was performed near Denver, where a spare coupler was found, purchased, modified, and installed in half a day.

Table 6. Range Master Maintenance Times During the Phase II Demonstration.

Day 1 – Pre-demonstration	8	hours	Install 0.75-inch screens & hydraulic pump repair
Day 2 – Pre-demonstration	8	hours	AC repair
Day 3 – Practice & demonstration	0	hours	
Day 4 - Demonstration	0.5	hours	Clean rear camera lens
Day 5 – Demonstration	4.5	hours	Pull out 0.75-inch screens
Day 5 – Demonstration	2.5	hours	Shifting repair – remote computer reset
Day 6 – Demonstration	6	hours	Hydraulic leak from blown filter gasket
Day 7 – Demonstration	3	hours	Shaker coupler replacement
Day 7 – Demonstration	1	hours	Tighten top port screen
Day 8 – Demonstration	1	hours	Reset remote computer
Day 8 – Demonstration	1	hours	Final MEC decontamination
Day 9 – Demonstration	1.5	hours	Final wash down
Total maintenance time	37	hours	Total maintenance time
Demonstration maintenance time	21	hours	Demonstration maintenance time

The Range Master's availability was calculated as a percentage of demonstration downtime (1-(21/216)) = 90.3%. The total Phase II maintenance and down time was 9.7%. This includes setup time to mount the 0.75-inch screens, hydraulic pump repair, and air conditioning repair.

4.4 TECHNOLOGY COMPARISON

Previous testing of the technology was described in the pre-proposal testing of the Range Master excavator and an independent screening unit (Phase I Final Report). This closely represents the current state of use of excavate-and-sift operations at MEC sites, where soils are excavated, hauled to a sifting unit, and fed through the screens. Screened items are inspected for MEC and disposed of. Sifted soils are returned to the site. During this pre-proposal test, the unmodified Range Master excavated an area equivalent to nine 100-ft x 100-ft grids, or about 2.1 acres. The dry excavated soils were fed to the original screening system, which is now scaled down in Range Master. Screened items were identified, sorted, and disposed of. The sifted soils were returned to the site. The cost for this conventional operation was $105,690, or ($105,690/9) $11,743.33 per 100-ft x 100-ft grid, or ($105,690/2.1 acres) $50,328.57 per acre. The soil conditions for this test were optimal (dry) and documented an excavation rate of 40 hours per acre.

Although the Phase II excavation proved to be inconsistent due to inexperience in excavator operation, it can be expected that Range Master will significantly reduce the time needed to excavate and sift high-density UXO sites. The Range Master Phase II remote demonstration documented a practical excavate-and-sift rate of 11 hours per acre at a cost of $46,235 per acre.

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5.0 COST ASSESSMENT

5.1 COST REPORTING

USA tracked the demonstration costs for the Phase II Range Master demonstration. The details are included in Table 7. Costs are broken out for USA and Timberline, and for the original demonstration schedule (first 5 days) and the extended demonstration (additional 4 days). Please note that Timberline did not charge for the original Phase II demonstration, nor did they include the mobilization/demobilization costs for Range Master.

Table 7. Cost Tracking.

Cost Category	Sub-Category	Details
Original Phase II Demonstration		
Start-up cost	Mobilization	$3,873.90
	Demonstration setup	$1,503.45
	Demonstration	$9,626.10
Capital costs	Range Master – sunk cost	$0.00
Demonstration operating cost	Timberline	$0.00
Original demonstration cost		$15,003.45
Extended Phase II Demonstration		
	USA costs	$6,013.80
	Timberline costs	$21,493.60
Extended demonstration cost		$27,507.40
Total Phase II demonstration cost		**$42,510.85**

5.2 COST ANALYSIS

This section is designed to assess the demonstration costs and extrapolate a more realistic cost estimate for fielding the Range Master.

5.3 COST COMPARISON

Previous testing of the technology was described in the pre-proposal testing of the Range Master Excavator and an independent screening unit (Phase I Final Report). This closely represents the current state of use for sifting operations at MEC sites where soils are excavated, hauled to a sifting unit, and fed through the screens. Screened items are inspected for MEC and are disposed of. Sifted soils are returned to the site. During this pre-proposal test, the unmodified Range Master excavated an area equivalent to nine 100-ft x 100-ft grids, or about 2.1 acres. The dry excavated soils were fed to the original screening system, which is now scaled down in Range Master. Screened items were identified, sorted, and disposed of. The sifted soils were returned to the site. The cost for this conventional operation was $105,690, or ($105,690/9) $11,743.33 per 100-ft x 100-ft grid, or ($105,690/2.1 acres) $50,328.57 per acre. The soil conditions for this test were optimal (dry).

The Phase II demonstration integrated this process on a common platform and performed the operation remotely on site. The same, but modified (now armored and controlled remotely), base carrier was used. The integrated screening unit was a scaled-down version of the same unit

used for the pre-proposal test. The sifted soil was retuned to the site in real time while the screened items were dumped for inspection. The soil conditions for the Phase II Demonstration were optimally dry. Note that the separately funded soil sieve test and pre- and post-excavation DGM are considered excess and are not included in the costs for practical Range Master use.

Table 8 extracts the costs associated with the practical demonstration. It includes mobilization for the Range Master, operator, mechanic, UXOSO, and project engineer, labor for the actual demonstration time (50 hours); Range Master cost; consumed fuel and hardware; site restoration; and demobilization. Note that, on an actual job, an additional UXO team would be required to handle disposal of any recovered UXO. The minimum team would consist of three personnel: a UXO Technician III (team leader), a UXOSO, and a UXO Technician II or III. For this part of the report, USA used the actual rates for the UXOSO.

Table 8. Practical Demonstration Costs.

Cost Element	Unit Cost	Cost for 5 days
Mobilization		
USA mobilization	UXOSO	$3,873.90
Timberline mobilization	Subtotal	$41,910.00
	Range Master $38,000	
	Support vehicle $2,437	
	Air fares $450	
	Labor $1,023	
Mobilization total		$45,783.90
Demonstration		
USA demonstration costs	$751.73 per day * 5 days	$3,758.65
Timberline labor and per diem	$2,109 per day * 5 days	$10,545.00
Range master	$4,000 * 5 days	$20,000.00
Support vehicle	$93.60 * 5 days	$468.00
Fuel and consumables	$450 * 5 days	$2,250.00
Demonstration total		$37,021.65
Demobilization		
USA demobilization		$3,873.90
Timberline demobilization	Subtotal	$28,910.00
	Range Master $25,000	
	Support Vehicle $2,437	
	Air Fare $450	
	Labor $1,023	
Demobilization total		$32,783.90
Practical Demonstration Total		$115,589.45
Total per 50-m x 50-m grid	$115,589.43/4 50-m grids	$28,897.36 per 50-m grid
Total per acre	$115,589.43/2.5 acres	$43,235.77 per acre
Total per 10-hour day	$115,589.43/50 hours	$23,117.89 per day

A significant savings in time and cost was demonstrated, although these costs must be tempered with the inexperience in excavating. The demonstration time per grid averaged (50 hr/4 grids) 12.5 hours per 50-m grid or 20.25 hours per acre. The pre-proposal test demonstrated an average 20 hours per 100-ft grid or 87.12 hours per acre. Although the Phase II excavation proved to be inconsistent due to inexperience in excavator operation, it can be expected that Range Master

will significantly reduce the time needed to excavate and sift high density UXO sites. The average cost per acre detailed in Table 8 was $46,235.77. The pre-proposal test sifted a total of nine 100-ft x 100-ft grids, or 2.1 acres at a cost of $50,328.57 per acre. This represents a savings in excavation time of 39 hours per acre (50 hours - 11 hours) and a potential cost savings of $4,093 per acre ($50,328 - $46,235).

6.0 IMPLEMENTATION ISSUES

6.1 COST OBSERVATIONS

The proposed cost for the Phase II demonstration was $13,500. This did not include any costs from Timberline, including all mobilization, labor, and per diem costs. This represented Timberline's commitment to the project. The practical demonstration costs were $115,589.43. The basis for determining more realistic real world work costs was based on the actual mobilization/demobilization and the demonstration costs prorated to the 50 hours of actual work time. From the prorated cost, the cost per 50-m grid, the cost per acre, and the cost per 10-hour day were calculated.

These prorated costs are based solely on the Phase II demonstration data of mobilizing equipment and personnel to excavate four 50-m grids. A more likely scenario would cover a larger area. This would allow the high mobilization/demobilization costs to be spread over a larger area.

6.1.1 Cost Drivers

Mobilization/demobilization, contiguous excavation area, soil and terrain conditions, and on-site maintenance are considered the major cost drivers. The Range Master’s weight requires a heavy-duty 9-axle trailer, with special permits and escorts required, to move it from place to place. The best estimate for Range Master transportation costs is $18/mile. Maintenance costs need to be considered in terms of time and material costs and availability. Most parts are available off-the-shelf, either new or used, worldwide. Maintenance of these items will be minimal. However, should the Range Master require depot-level maintenance, either bringing the depot on site or returning the Range Master to the depot will add significant cost and time.

6.1.2 Life-Cycle Costs

The life-cycle costs for Range Master #1 include the purchase price ($100,000), plus the project start-up task funded by USAESCH ($25,000), plus the Phase I and Phase II development costs, including nonrecurring engineering and design ($804,470). The expected life of the scraper is estimated at 5,000 hours, or 500 10-hour work days. Operation and maintenance costs are included in the Range Master rental rate of $4,000 per day ($2,000,000). This brings the expected life-cycle cost of Range Master #1 to a total of $2,929,470.

The current Range Master rental rate of $4,000 per day is anticipated to maintain the system throughout its expected life. The estimated transportation cost of $18 per mile can be used as a guide for planning (this estimate does not include personnel mobilization/demobilization costs).

6.2 PERFORMANCE OBSERVATIONS

6.2.1 Safe and Easy-to-Use Remote Control

The Range Master operator demonstrated skill in safe, remote control operation. The system was easier to use remotely than via manual operation due to a combination of excellent visibility

provided by the video system and the telemetry controls (refer to Section 4.3.5, Ease of Use). There were no unintentional detonations or any MEC-related damages to Range Master. The single remote control key, provided to the UXOSO each time the remote system was serviced, prevented any accidental remote control operation (refer to Section 4.3.1, System Safety Assessment).

6.2.2 Improved Excavation Rate

The excavation rate was compromised by the operator's lack of experience in scraper operation. This was the major reason the planned excavation rate of 1 to 2 acres per day ended up averaging 2 days per acre. For all future Range Master deployments, Timberline will use an experienced excavator and train them in remote control operation.

Despite this setback in excavation rate, the Phase II demonstration greatly reduced the rate per acre over conventional excavate-and-sift operations (11 hours per acre versus 40 hours per acre).

6.2.3 DGM Site Conditions Not Improved

Post-excavation DGM site conditions were not improved. Various reasons underlie this lack of improvement, including the inexperience in production excavation that resulted in an uneven excavation depth (0 to 18 inches below ground). As a bombing range, there is a significant amount of metal below Range Master's planned excavation depth of 12 inches.

6.2.4 Better than Planned Downtime

Downtime was better than expected. Having the demonstration near a large city where a spare power screen coupler was found, purchased, modified, and installed in half a day contributed to this success.

6.2.5 Reduced Excavation Costs

The excavation rate, albeit uneven, proved to be much faster than conventional excavate-and-sift operations. Range Master demonstrated 11 hours per acre versus a conventional rate of 40 hours per acre. The Phase II demonstration showed the potential to reduce excavation costs by $4,093 per acre.

6.3 SCALE-UP

No scale-ups are required to field Range Master in either manual or remote control mode. The larger the site, the smaller the proportion of mobilization/demobilization costs will be.

6.4 OTHER SIGNIFICANT OBSERVATIONS

Over-driving Range Master is still an issue. When the depth of cut and forward velocity are too great, the power screen can become overloaded; as a result, unprocessed soil falls into and fills the hopper. Once the hopper is full, the unprocessed soil spills back onto the site. An experienced excavator operator would better match depth of cut and forward speed. Excavating to a consistent planned depth may require additional passes.

6.5 LESSONS LEARNED

6.5.1 Range Master Design Concept Sound

In terms of performance, the Phase II Range Master demonstrated safe and effective remote control operation. The inexperience of the operator in scraper operation proved to be a limiting factor in maintaining a 12-inch excavation depth. The design concept is solid. With the deployment of operators experienced in scraper use and trained in remote operation, Range Master is ready for additional demonstrations or production use.

6.5.2 Experience in Scraper Operation

The Phase II operator demonstrated great skill in safely and effectively maneuvering the Range Master throughout the demonstration. However, the operator's inexperience in excavation resulted in a scalloped excavation depth ranging from just barely scraping the surface to more than 18 inches below surface. An operator with excavation experience would have used the depth of cut more effectively to control forward speed and provide a more uniform excavation.

6.5.3 Site Expectations

It was originally expected that Range Master would excavate the grids in the long 250-m (north/south) direction versus the shorter 50-m (east/west) direction to minimize turnaround times and maximize production. However, in actuality the system hopper was filled, mostly with unprocessed soil, prior to completing a 50-m run. Since keeping the dump piles off the demonstration grids was desirable, the shorter 50-m run was used throughout the demonstration.

The prairie grass was not expected to present an issue for Range Master. However, this species of vegetation has long runners that would often blind even the primary 2.0-inch screen. Range Master needs to clear the vegetation in one pass, or a means of clearing vegetation from the screens needs to be developed.

Although BT#2 provided a good opportunity for the Phase II demonstration, the fact that it was a former bombing target, with significant amounts of metal below the Range Master's excavation depth (typically 12 inches), was unfortunate. Range Master is better suited to live sites where the majority of metal is within the first 12 inches of the surface (e.g., artillery, mortar, grenade, or strafing ranges).

6.5.4 Design Improvements

From the Phase II Demonstration, a method to measure and assess Range Master excavation depth needs to be established and a track guidance feature needs to be implemented.

6.6 END-USER ISSUES

End-user issues and concerns are detailed in Section 1.5.

6.7 APPROACH TO REGULATORY COMPLIANCE AND ACCEPTANCE

Approval to use the Phase II Range Master (armored and remote controlled) on the FLBGR BT#2, was accomplished by an ESS addendum. This addendum went through the normal ESS process and was approved by the DDESB. This was a range-specific approval and not a blanket endorsement to use Range Master on any range. A blanket DDESB endorsement of Range Master could be attempted, but the most likely scenario would be to include the use of the Range Master via an ESS addendum.

Prior to deploying the Range Master to the specific grids on BT#2, the state dig-safe group was consulted to ensure that no state, county, or city utilities would be a concern. A similar procedure may be required through Range Control on active ranges.

The high power video link (up to 4 watts) did not require frequency allocation at the Phase II demonstration site. However, on active ranges, this allocation may be required.

7.0 REFERENCES

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USA Environmental, Inc. 2005. Phase II Demonstration Plan for Test, Evaluation, and Demonstration of the Range Master, a Tool for Excavation of Heavily Contaminated UXO Sites, ESTCP Project UX-0327. June.

USA Environmental, Inc. 2007. Phase II Final Report Remote Excavation of Heavily Contaminated UXO Sites ESTCP Project MM-0327.5 September.

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APPENDIX A

POINTS OF CONTACT

POINT OF CONTACT Name	ORGANIZATION Name Address	Role in Project
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